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MERQ EVALUATION SYSTEM

Multi-Dimensional Assessment of Technology Maturity Conference

10 May 2006



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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 10 MAY 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE MERQ Evaluation System				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, Turbine Engine Division, Wright Patterson AFB, OH, 45433				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002184. Presented at the Air Force Research Laboratory Seminar/Workshop on Multi-Dimensional Assessment of Technology Maturity in Fairborn, OH on 9-11 May 2006.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 27	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



Agenda



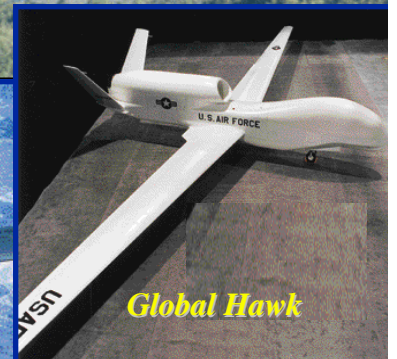
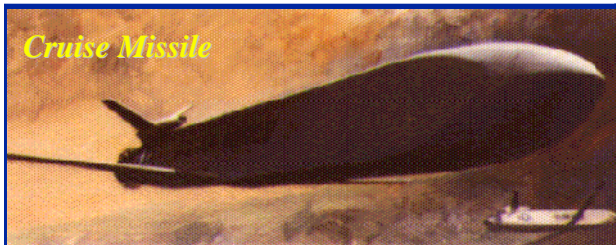
- **Background**
- **Description**
- **Application/Example**
- **Risk Assessment Tool**
- **Summary**



What is IHPDET?

Integrated High Performance Turbine Engine Technology

The IHPDET program is a joint government and industry effort focused on developing technologies for more affordable, more robust, higher performance turbine engines for current and future aircraft and missile systems.





Who is in IHPTET?



A Coordinated DoD, NASA, & Industry Effort



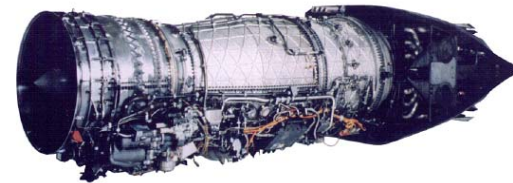
Turbine Engine ‘Building Block’ Process

APPLIED RESEARCH (6.2)



ADVANCED TECHNOLOGY DEVELOPMENT (6.3)

Seamless Development Process



APSI JTDE and JETEC
“ENGINE” DEMONSTRATORS



ATEGG and JTAGG “CORE”
TECHNOLOGY DEMONSTRATORS

Seamless Contractor Planning

TECHNOLOGY TRANSITION





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MERQ DESCRIPTION



The **M**aterials
Environment
Reaction
Quality
Evaluation System



Technology Readiness Levels



**System Test, Flight
and Operations**

9 - Actual system "Flight Proven" through successful mission operations

8 - Actual system completed and "Flight Qualified" through test and demonstration

**System/Subsystem
Development
(SDD)**

7 - System prototype demonstration in an operational environment

**Technology Demonstration
(ATEGG/JTDE)**

6 - System/Subsystem model or prototype demonstration in a relevant environment

5 - Component and / or breadboard validation in relevant environment

**Technology
Development (Rig Testing)**

4 - Component and / or breadboard validation in laboratory environment

**Research to Prove
Feasibility**

3 - Analytical and experimental critical function and / or characteristic proof - of - concept

**Basic Technology
Research**

2 - Technology concept and / or application formulated

1 - Basic principles observed and reported

Materials
Environment
Reaction
Quality
Materials
Environment
Reaction
Quality
Materials
Environment
Reaction
Quality
Materials
Environment
Reaction
Quality

Material Properties Rating (M)

0	Sales staff says “this is good stuff”
2	Coupon data with some extrapolation
3	Coupon data at relevant conditions
4	Subcomponent data with extrapolation
5	Subcomponent data with interpolation
6	Subcomponent data at relevant engine test conditions (1-2 data points)
7	Subcomponent data at relevant engine test conditions (3+ data points)
9	-3σ production values

Environment (E)

0	Component engineer: “what engine?”
2	Preliminary design cycle
4	Detailed design
6	Detailed design with monitored instrumentation during engine test
7	Previous instrumented engine test with similar environment
9	Previous instrumented engine test with nearly identical environment

Reaction to Environment (R)

0	Design engineer: “it might work”
1-3	FEM alone (no additional testing)
2	Subscale component rig test @ other conditions
4	Subscale component rig test @ other conditions + appropriate FEM
4	Like component rig test @ other conditions
5	Subscale component rig test @ relevant conditions
5	Actual component rig test @ other conditions
6	Like component rig test @ other conditions + appropriate FEM
6	Subscale component rig test @ relevant conditions + appropriate FEM
7	Like component rig test @ relevant conditions
7	Actual component rig test @ other conditions + appropriate FEM
8	Actual component rig test @ relevant conditions
8	Like component rig test @ relevant conditions + appropriate FEM
9	Actual component rig test @ relevant conditions + appropriate FEM

Quality (Q)

0	Production Manager: “We have a nice viewgraph of it”
1	Visual inspection alone
2	Nonvalidated inspection with unproven manufacturing process
4	Nonvalidated inspection with demonstrated manufacturing process
5	Nonvalidated inspection techniques with proven manufacturing process
6	Validated inspection with unproven manufacturing process
7	Validated inspection with demonstrated manufacturing process
9	Validated inspection with proven manufacturing process

Component Confidence Rating (C)

$$C = \sqrt[4]{\text{MERQ}}$$



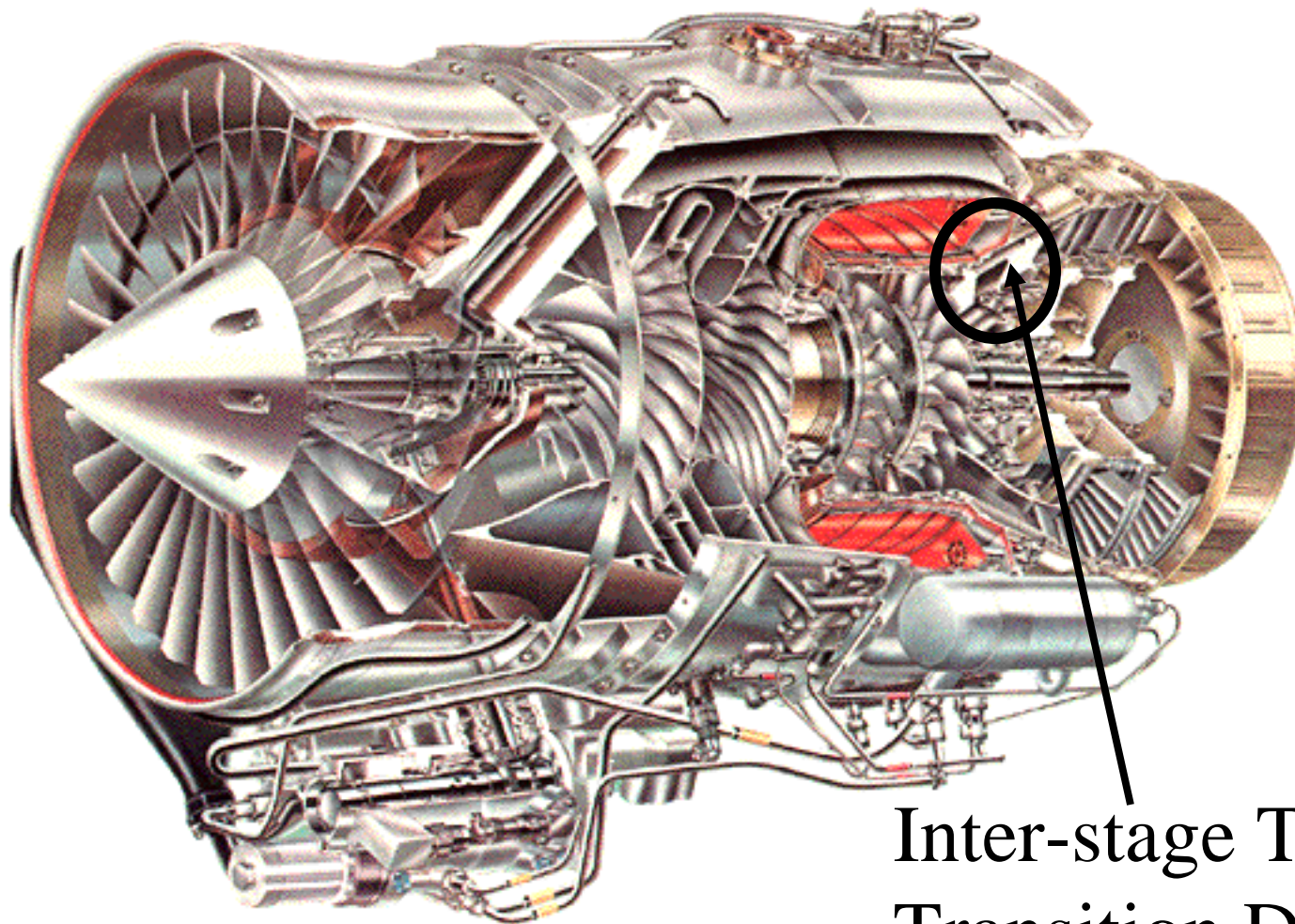
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MERQ Example



Inter-stage Turbine
Transition Duct

F109 for Illustration purposes only- F109 not the real example



MERQ Evaluation



- **Materials -Silicon Nitride (Ceramic)**
 - Increase temperature capability uncooled
 - Lighter than metal, more brittle, not as strong
 - Subcomponent data at higher temperatures;
Limited engine testing at lower temperatures

0	Sales staff says “this is good stuff”
2	Coupon data with some extrapolation
3	Coupon data at relevant conditions
4	Subcomponent data with extrapolation
5	Subcomponent data with interpolation
6	Subcomponent data at relevant engine test conditions (1-2 data points)
7	Subcomponent data at relevant engine test conditions (3+ data points)
9	-3 σ production values



MERQ Evaluation



- **Environment**
 - **Physics based detailed design**
 - **Pressures, temperatures, stresses into/out of component**
 - **Metal Inter-stage turbine transition ducts tested previously but not at this high a temperature**

	0	Component engineer: “what engine?”
	2	Preliminary design cycle
→	4	Detailed design
	6	Detailed design with monitored instrumentation during engine test
	7	Previous instrumented engine test with similar environment
	9	Previous instrumented engine test with nearly identical environment



MERQ Evaluation



- **Reaction to Environment**
 - **Metal Inter-stage turbine transition ducts tested previously but not at this high a temperature**
 - **No way of monitoring component (strain gages, borescope for cracks) during test**

0	Design engineer: “it might work”
1-3	FEM alone (no additional testing)
→ 2	Subscale component rig test @ other conditions
4	Subscale component rig test @ other conditions + appropriate FEM
4	Like component rig test @ other conditions
5	Subscale component rig test @ relevant conditions
5	Actual component rig test @ other conditions
6	Like component rig test @ other conditions + appropriate FEM
6	Subscale component rig test @ relevant conditions + appropriate FEM
7	Like component rig test @ relevant conditions
7	Actual component rig test @ other conditions + appropriate FEM
8	Actual component rig test @ relevant conditions
8	Like component rig test @ relevant conditions + appropriate FEM
9	Actual component rig test @ relevant conditions + appropriate FEM



MERQ Evaluation



- **Quality**

- **Silicon Nitride components of similar size fabricated previously**
- **Surface inspection validated, internal inspection by destruction only**

0	Production Manager: “We have a nice viewgraph of it”
1	Visual inspection alone
2	Nonvalidated inspection with unproven manufacturing process
4	Nonvalidated inspection with demonstrated manufacturing process
5	Nonvalidated inspection techniques with proven manufacturing process
→ 6	Validated inspection with unproven manufacturing process
7	Validated inspection with demonstrated manufacturing process
9	Validated inspection with proven manufacturing process



MERQ Evaluation



Component Confidence
Rating (C)

$$C = \sqrt[4]{\text{MERQ}}$$

$$C = \sqrt[4]{5426} = 3.9$$

Is risk acceptable?



MERQ Evaluation



C=3.9 Not acceptable risk, need C=6

Action: Run instrumented columbium metal duct (limited life)

- Material is a 9, -3 σ production values
- Environment stays at 4, detailed design
- Reaction to Environment is at 7, like component rig test at relative conditions
- Quality is a 9, validated inspection with proven manufacturing process

$$C = \sqrt[4]{\text{MERQ}}$$

$$C = \sqrt[4]{9479} = 6.9$$



MERQ Evaluation



After engine test with instrumented columbium metal duct:

- Environment goes from 4 to 9 (Previous instrumented test with nearly identical environment)
- Reaction to Environment goes from 4 to 9 (Actual component rig test at relative conditions + appropriate FEM)

$$C = \sqrt[4]{\text{MERQ}}$$

$$C = \sqrt[4]{5996} = 7.0$$



MERQ Evaluation



MERQ Flexible/Adaptable Mechanical/Structural Evaluation

- Turbine Engine (Temp, Pressure, Cyclical Loads, Material)
 - Computer Chip (Temp, Material)
 - Aircraft Tire (Temp, Pressure, Friction, Material)
 - Radar (Temp, Pressure, Material)
 - Aircraft Wing (Temp, Pressure, Cyclical Loads, Material)
 - Bridge cable (Temp, Tension, Material)
- etc.



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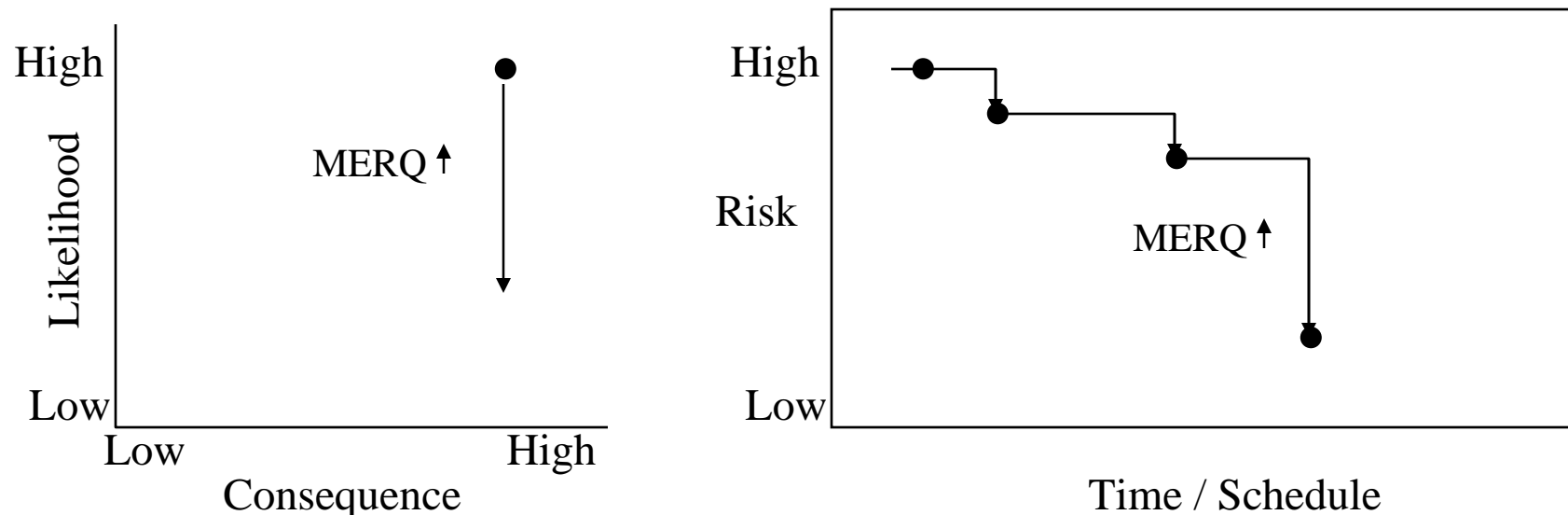


Risk Assessment Tool



Risk Management* Plan – MERQ can help quantify Mechanical/Structural Risks

1. Graphical Risk Prioritization (Likelihood of Failure versus Consequence of Failure)
2. Risk Status Chart/Profile (Risk Waterfall)



*Risk Management Guide For DOD Acquisition, Jun 03, DOD DAU



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Summary



- **MERQ developed for Turbine Engines**
- **MERQ for Mechanical/Structural Evaluation**
- **MERQ establishes quantitative risk assessment**
- **MERQ is flexible and could be tailored to be applicable across many technical areas**